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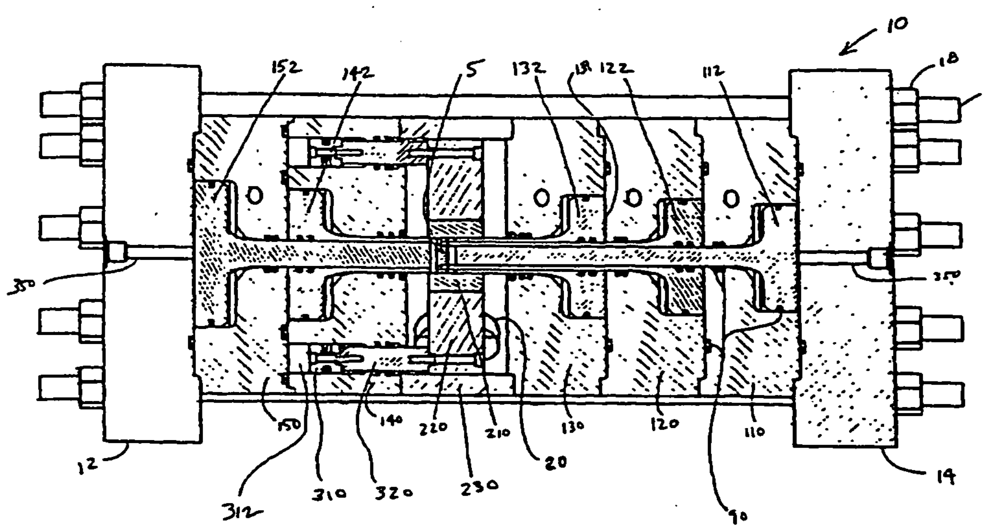
(54) Title: HYDRAULIC POWDER PRESS



(57) Abstract: A powder press for forming a work piece (5) from powdered material includes at least one force applying assembly (360) and at least one punch (112). The punch (112) is preferably monolithic. The punch (112) is driven by a force applying assembly (360) directly applying force to the force receiving end of the punch without the need for any adapters. The area of the force receiving end of the punch directly corresponds to the area of the work piece (5) being formed. A plurality of force applying assemblies may be present, and are preferably axially fixed relative to one another. The press does not require use of the platens of conventional presses nor a massive external frame.

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HYDRAULIC POWDER PRESS

Field of the Invention

This invention relates to a press for forming a work piece from a particulate material and, in particular, a compact sized, portable and economical press for forming a work piece from powdered metals. The press can be part of a modular pressing assembly.

Background of the Invention

In the field of powder metallurgy, fine metal powders are compressed into the form of a work piece in a die under high pressure. The procedure is typically carried out in huge oversized machines referred to as powder presses. In these presses, pressure is applied to the metal powder by at least one movable punch. The pressure applied to the work piece by way of the punch, or punches, can be applied, for example, mechanically or through the use of hydraulic rams. An example of a powder press using a hydraulic ram is shown in U.S. Patent No. 3,788,787 to Silbereisen et al. Silbereisen et al. involves a powder press having a vertical orientation and upper and lower hydraulic cylinder assemblies. The upper hydraulic cylinder assembly is connected to a massive cross head, or platen. A press punch, is in turn connected to the cross head and moves downwardly into a mold cavity in the die. This action presses the metal powder within the die to form a compressed solid work piece having the desired height and shape. A lower punch is fixed relative to the frame.

The Silbereisen, et al. press is representative of powder presses presently known in the art in that 1) it is designed to accommodate a variety of different work pieces by allowing for interchangeability of the tool matrix or die and 2) the distance the ram(s) travels or "stroke" is relatively fixed. In this "generic" press it is therefore necessary to compensate for the "fixed" stroke by adapting the tool and die

and appropriately connecting them to the ram(s) in order to produce a given part or work piece. Such adaptation typically involves large structure and results in large distances between the source of force moving the ram and the actual part being produced. These large distances then translate into inaccuracies in alignment between the punches when they reach the die to form the work piece.

The powder from which the work piece is formed is conventionally introduced to the die by a powder feed shoe that allows powder to fall gravitationally into the open upper end of the die as the feed shoe travels across the die. As the powder is compressed by the punches, density gradations in the powder create shear forces within the powder. To contain the shear forces and other forces created by misalignment of the punches, conventional presses rely on large overall size and weight and on massive moving platens to maintain proper alignment during operation. In particular, the platens of conventional presses and the frame members holding and guiding the platens, are also very large and very heavy in order to maintain proper alignment of the punches and the die. Because of the tremendous forces employed in the press, any misalignment can cause catastrophic failure of the press. As a result of all this required additional structure, presses of this type typically stand greater than 20 feet high and weigh more than 50 tons.

Further contributing to the massive size of these presses is an integrated energy source. That is, each press has its own built in energy source which typically is very large considering the amount of energy needed to press a work piece.

A commercially available hydraulic automatic press known as the TPA H manufactured by Dorst Maschen und Anlagebau readily illustrates the massive size of these conventional presses. The TPA H press provides, at the lower end of the press, a first hydraulic cylinder fixed relative to the frame

of the press and having a first piston that moves vertically within the first hydraulic cylinder. A second piston moves vertically within the first piston such that the first piston acts as a second hydraulic cylinder within which the second piston operates. The TPA H press also provides an upper hydraulic cylinder fixed relative to the frame of the press. The upper hydraulic cylinder has an upper piston that moves vertically relative to the upper hydraulic cylinder. Similarly to those of other conventional presses, the punches used with the TPA H press are spatially separate from the various hydraulic pistons and are held in position by large platens. Hence, this press has, as is typical with other conventional presses, a source of energy for moving the punches at a remote location from the energy or force receiving end of the punch. This press also has a large external frame to compensate for the shear forces on the powder and the misalignment of the punches due to large travel distances.

The moving mechanism in a typical press can be, as in Silbereisen, et al., a hydraulic piston cylinder mechanism. Further drawbacks to the typical powder press as shown in Silbereisen, et al. include the requirement for an extensive set-up procedure prior to starting a production run for a given work piece. During set-up, the various punches and the die must be properly aligned relative to one another and attached to their respective platens. In addition, movement of the platens must be coordinated such that the powder in the die is compressed at a predetermined rate by each punch. Such coordination usually results in different platens moving at different rates for different periods of time. Therefore, set-up is a time consuming operation that can take one to three days to complete and must be performed by highly skilled operators. When the next work piece is to be made, the press

must be disassembled and reassembled, resulting in a significant down time for the entire press.

This need for massive platens movable relative to one another and thus the requirement of long punches, and the requirement for sufficient floor space to permit assembly and disassembly, further contributes to the massive size of the presses, which can be around 25 or more feet high. They also involve a large number of massive, relatively moving parts whose movements must be precisely controlled, with the result that they are very complex and very expensive, and can cost for example, more than a million dollars for a single press. These presses are typically installed with their bases at least 6 feet underground and require reinforced foundations. Also, frequent breakage of parts during assembly and disassembly results in added costs associated with the conventional press. Each conventional press is manufactured as a specific size, for example, 220 ton, 750 ton, etc., each size having the ability to make only a certain range of parts. Further, the large distances between moving parts of conventional presses magnifies the effect of manufacturing tolerances. As a result, very large pieces of conventional presses must be manufactured to very tight tolerances, making manufacture of these pieces very expensive. Additionally, as discussed above, each conventional press has an integrated force producing assembly. All of these factors contribute to high operating costs that must eventually be recouped in the price of the work pieces produced. Moreover, these conventional powder presses are considered to be permanent fixtures and lack any kind of portability.

Summary of the Invention

An apparatus and method of the present invention perform the pressing function of a conventional powder press while, at the same time, allowing the use of a substantially smaller, lighter, portable and less expensive apparatus than a

conventional powder press. A press of the present invention can be about 12 inches in diameter and about 28 inches long, for example, as opposed to about 25 feet high and about six feet across for a conventional press. A press of the present invention can be preferably manufactured to produce one specific work piece and therefore need not be adjustable thereby requiring long down times to set-up. Alternatively, in some embodiments, the present invention press can be manufactured to produce one specific work piece for as long as needed and then retooled to produce another work piece. Moreover, the present invention presses have outside independent power sources such that a number of presses can be attached to one power source, greatly conserving resources and space. The greatly reduced size, weight and complexity of a press of the present invention allows a press to be manufactured at a much lower cost and in a much shorter time than a conventional press.

Presses of the present invention have a substantially simplified structure. In embodiments of this invention, the motive force is applied directly to a force receiving end of one or more punches without the need for intervening platens. The punches are preferably monolithic devices that include a work-pressing end and a force-receiving end, although in some embodiments interchangeable work pressing attachments are provided at the work piece forming end of the punch. In embodiments involving a plurality of punches moving in the same direction during formation of a work piece, the force applying mechanism for one punch is preferably axially fixed relative to the force applying mechanism for another punch. For example, each punch is preferably associated with a hydraulic cylinder, with the plurality of hydraulic cylinders being fixed relative to one another. Particularly in embodiments comprising a plurality of coaxial hydraulic cylinders, adjacent cylinders may be in contact with and

attached to one another to provide a particularly compact arrangement. The present invention press optionally includes means for creating a substantially uniform distribution of powder in the die. By including such means the powder in the die can be pressed relatively squarely and perpendicularly, reducing the requirement for huge platens and structure to maintain alignment of the press during pressing. Add to this the relatively short distances the punches of the present invention travel in forming the work piece and the result is the virtual elimination of shear forces on the powder during pressing. This contributes to more precise part geometries and tolerances.

Brief Description of the Drawings

The foregoing and further objects, features and advantages of the present invention will be described in or be apparent from the following description of embodiments, with reference to the accompanying drawings, where like numerals are used to represent like elements and wherein:

Fig. 1 is an end view of a press of the invention;
Fig. 2 is a side view of a punch of the invention
Fig. 3 is a sectional view along section line II-II in Fig. 1
Fig. 4 is a sectional view of an embodiment of the invention;
Fig. 5 is a side view of an embodiment of the invention;
Fig. 6 is a sectional view of an alternative embodiment of the present invention; and
Fig. 7 is a schematic drawing of a pressing assembly according to the present invention.

Detailed Description of Preferred Embodiments

In an embodiment of the present invention a powder press for forming a work piece comprises at least one punch having an end for pressing a powder material to form the work piece. The punch is operatively associated with a first end of a piston that also has a second force receiving end. In one embodiment, the punch that is operatively associated with the

first end of the piston is removable therefrom. Alternatively, the punch operatively associated with the first end of the piston comprises a single monolithic part. At least one force applying assembly is configured to apply pressing force directly to the force receiving end. There is a die to receive and contain the powder. The die has a hole positioned to receive the end of the punch. There are means associated with the die for creating a substantially uniform distribution of powder in the die and a source of power for engaging the force applying assembly. In a preferred embodiment the means associated with the die for creating a substantially uniform distribution of powder in the die comprises a powder fluidizing apparatus. An example of such an apparatus is the subject of U.S. Patent No. 5,885,625 to Beane et al. hereby incorporated in its entirety herein by reference. The source of power is external to and independent from the powder press. The powder press can further comprise at least one second punch extending in a second direction that is opposite that of the direction of the first punch and towards the die. The second punch can be fixed or alternatively can be operatively associated with a first end of the second piston which also has force receiving end.

In a further embodiment, the powder press assembly comprises an independent power source and at least one pressing module remotely associated therewith. Typically the independent powder source is free standing and remotely located from the press. The pressing module is preferably comprised of at least one punch having an end for pressing a powder material to form the work piece. The punch is operatively associated with a first end of a piston having a second force receiving end. There is at least one force applying assembly configured to apply pressing force directly to the force receiving end of the piston. Each pressing module is operatively and reciprocally connected to and receives

power from the independent power source. There is a die to receive and contain the powder. The die has a hole positioned to receive the end of the punch. The press assembly can further comprise means attached to the die for delivering powder into the die and creating a substantially uniform distribution of powder in the die. The assembly can comprise a plurality of pressing modules remotely associated with the independent power source. In such instances the press assembly further comprises at least one pressing station remotely associated with and receiving power from the independent power source. Each of the pressing modules is reciprocally attached respectively at one of the pressing stations.

In embodiments of the invention, a powder press has at least one punch and at least one force applying assembly. Each punch has a work piece forming end for forming the work piece and a force receiving end portion. The punches are preferably monolithic, but in embodiments can be comprised of a work piece forming punch operatively associated with a second end of a piston. Each force applying assembly applies force to the force receiving end portion of a punch along the axis of the punch. Each force applying assembly is preferably axially fixed relative to a frame so that it cannot move along the axis of the punch. The punches are, in some embodiments, arranged so that the work piece forming ends of one or more punches are arranged to form the same side or alternatively, opposite sides of the work piece. The long axes of the punches can be arranged horizontally, vertically or at any other angle relative to the horizon, particularly where a fluidizing powder feeder is utilized to charge the die. An example of such a fluidizing powder feeder is shown in U.S. Patent No. 5,885,625 to Beane et al. hereby incorporated by reference herein in its entirety. Some or all of the force applying assembly can be, for example, a hydraulic force

applying assembly, a pneumatic assembly or mechanical force applying assembly.

In an embodiment of the invention for forming a work piece of a given height (H_{wp}), from a powder having a powder fill ratio (R_{pf}), a powder press has at least one piston cylinder having a piston slidable within it. The powder fill ratio of a powdered material is typically understood in the art to be the volume of the loose powder divided by the volume of a part made by compressing the same loose powder at a given force. The values for the powder fill ratio for a given material are generally known or alternatively can be measured.

The piston has a force receiving end within the cylinder and a work piece forming end extending beyond the cylinder. In contrast to typical powder presses wherein the force receiving end of the punch is attached to or at least in contact with any number of adapters before engaging the motive force, in the present invention the force receiving end directly engages a motive force (F_{m1}) for sliding the piston within the first piston cylinder. This sliding within the cylinder acts to generate a force that is directly applied to the first surface of the work piece (F_{wp1}). Additionally, unlike traditional presses, the surface area of the force receiving end of the piston directly corresponds to the surface area of the part itself. Preferably, the force receiving end has a surface area (A_{fr1}) approximately equal to or greater than:

$$\frac{A_{wp1} \times F_{wp1}}{F_{m1}},$$

wherein A_{wp1} is the surface area of the work piece forming end of the first piston.

The respective areas of the force receiving ends of a plurality of pistons correspond directly to the surface area of the work piece being formed and are preferably set so that the work piece forming ends of the pistons press on the powder/work piece with the same predetermined pressure. Particularly in embodiments in which a uniform hydraulic

pressure is provided by the hydraulic pressure source, a uniform work piece pressing pressure can be achieved by having the same mathematical relationship that exists between the area of the force receiving end and the area of the work piece forming end of one piston be the same as a mathematical relationship between the area of the force receiving end and the area of the work piece forming end of another piston. This is particularly convenient where the press is designed for repeated production of the same part.

The press also comprises a die for defining the outer surface of the work piece. The die is preferably annular but can be any shape appropriate to define the work piece being formed. The die has a hole, which is positioned to receive the work piece forming end of or attachment on the piston. There is also an opening in the die to receive the powder. One or more piston cylinders can be positioned on the same side or opposite sides of the die. Therefore, the work piece forming end of a particular piston can extend in the same direction or in an opposite direction to the work piece forming ends of other pistons. Alternatively one of the pistons - the opposing one can be fixed, e.g. an anvil.

In this embodiment wherein the piston cylinders are all on the same side of the die, to form the work piece, the distance the first piston slides toward the die (the stroke) to form the work piece is approximately equal to the desired height of the work piece multiplied by the fill ratio of the powder being used less the height of the work piece $(H_{wp} \times R_{pf}) - H_{wp}$. To eject this work piece, the first piston further slides toward the die for a distance that is approximately equal to the height of the work piece. Hence the full stroke for ejection of the work piece is approximately equal to the height of the work piece x fill ratio of the powder.

In a further embodiment the present invention further comprises at least one second piston cylinder having a second

piston reciprocally slidable within it. The second piston, like the first piston, has a force receiving end located within the cylinder and a work piece forming end for forming a second surface of a work piece. The work piece forming end extends beyond the cylinder. The force receiving end directly engages a motive force F_{m2} for sliding the piston(s) within the second piston cylinder(s) to generate a force F_{wp2} to be applied to the first surface of the work piece. The force receiving end has a surface area A_{fr2} approximately equal to or greater than:

$$\frac{A_{wp2} \times F_{wp2}}{F_{m2}}$$

Wherein, A_{w2} is the surface area of the work piece forming end of the second piston.

In this embodiment the stroke for forming the work piece comprises both the first piston and the second piston each respectively sliding toward the die for a distance that is approximately equal to:

$$\frac{(H_{wp} \times R_f) - H_{wp}}{2}.$$

To eject the work piece, the second piston further slides toward the die for a distance that is approximately equal to H_{wp}. The total stroke for ejecting the work piece comprises the second piston sliding toward the die for a distance that is approximately equal to $H_{wp} \times R_{pf}$ the die.

In embodiments, a plurality of the piston cylinders are fixed relative to each other. Some of the second ends of the pistons can extend beyond their respective cylinders in the same direction, for example to provide concentric punches, while others can extend in a direction opposite the direction in which second ends of other pistons extend beyond their respective cylinders in order to press the opposite side of the work piece. Each piston cylinder and piston therein corresponds to a different level of the work piece to be formed.

Some or all of the piston cylinders can be hydraulic cylinders with the pistons being hydraulically operated. In the case of some or all of the piston cylinders being hydraulic cylinders, the piston cylinders can share a common hydraulic fluid pressure source or can have hydraulic fluid sources with the same or different pressures. The hydraulic pressure of the hydraulic fluid delivered to each hydraulic piston may be individually controlled by separate valves. Further, the valves may be, for example, controlled by a processor.

Piston cylinders that are adjacent to each other can be in contact with and attached to each other. This helps enhance the compactness of the structure and permits individual parts to have multiple functions. For example, the end of a part defining a cavity of one piston cylinder may also define the head of an adjacent piston cylinder. Additionally, in preferred embodiments, the first piston within each succeeding first piston cylinder extends through and is axially movable along an inner peripheral surface defining a cylindrical void through a directly preceding first piston. Likewise, the second piston within each succeeding second piston cylinder extends through and is axially movable along an inner peripheral surface defining a cylindrical void through a directly preceding second piston.
Figs. 3-6 show an embodiment of the invention wherein the punches are hydraulic pistons and the cylinders are hydraulic cylinders in which the pistons operate.

Fig. 3 shows an embodiment of the present invention wherein there are a plurality of first piston cylinders 110, 120 and 130. First piston or first punch(s) 112, 122 and 132 operate within first cylinder(s) 110, 120 and 130, respectively. Similarly, there are a plurality of second pistons or punches 142 and 152 operating within second cylinders 140 and 150, respectively. Seals 90 are located

throughout the press to contain the hydraulic fluid. Fig. 3 shows second punch 142 having a shaft portion 126 and a piston portion 128. The shaft portion 126 has a work piece forming end 123 at the end opposite the piston portion 128. The piston portion 128 has a retraction surface 121 and a pressing (force receiving) surface 129. The retraction surface 121 and the pressing surface 129 are acted upon by hydraulic fluid in order to move the second punch in a retraction direction A and a pressing direction B, respectively. Hydraulic fluid moves through inlet/outlet openings (not shown in Fig. 3) located at or near each end of each cylinder. The remaining punches have a similar construction to the second punch shown in Fig. 3. All punches except the outermost punches (first punch 112 and second punch 152 in Fig. 3) have a longitudinal hole, shown as 127 in Fig. 3, throughout their length. In the case of first punch 122, longitudinal hole 127 allows the shaft portion of first punch 112 to pass through second punch 122.

Fig. 4 is a cross sectional view of the second cylinder 120 showing a pressing hydraulic fluid passage 124 and a retracting hydraulic fluid passage 125. Pressing hydraulic fluid passage 124 provides a conduit for hydraulic fluid from a pressure source outside of the press (360 in Fig. 5) to the pressing surface of the punch adjacent a particular cylinder. In the case of the second cylinder shown in Fig. 4, the pressing hydraulic fluid passage 124 channels hydraulic fluid from the outside source to the force receiving end 139 of first punch 132 in order to move first punch 132 in the B direction towards the die in Fig. 3. To form the work piece, the distance the first piston moves toward said die is approximately equal to the desired height of the work piece multiplied by the powder fill ratio for the powder being used in the die less the height of the work piece $(H_{wp} \times R_{pf}) - H_{wp}$. Thus the stroke for the present invention directly corresponds to the part geometry, in this instance its height. The

retracting hydraulic fluid passage 125 channels fluid from the pressure source 360 to the retraction surface 121 of the first punch 122 in order to move the first punch 122 in the A direction in Fig. 3.

While the first cylinder 120 and the second punch 122 have been described as examples, the other cylinders and punches of the invention may operate similarly. Further, by relocation of the hydraulic fluid passages and addition of separate cylinder heads, the respective cylinders can be separated if desired. However, the simpler arrangement shown in Fig. 3 is preferred.

Fig. 3 shows die 210 held in place by a die holder 220, which is, in turn, positioned within a die housing 230. These parts could be unified into a simpler part, or further subdivided, if desired. The work piece forming ends of first, punches 212, 222, 232, and second punches 242, and 252 are received within the die 210. Material from which a work piece is to be formed is introduced into the die 210 through a conduit (no shown) and is preferably fluidized in accordance with any known fluidization method and compressed by the work piece forming ends of the punches as a result of the punches being moved within the respective cylinders due to the force applied to the pressing surface of each punch by the hydraulic fluid.

The material from which the work piece is formed can be, for example, metal powders, ceramic powders, other powders, flakes, fibers or sheets of ceramics, polymers, carbides, cements or the like. For ease of reference throughout the specification and claims, such materials are referred to as "powders."

The die 210 and the die holder 220 are preferably movable from left to right in the embodiment shown in Fig. 3 within the die holder 230 to facilitate ejection of a formed workpiece. For example, the die and die holder may be moved

by applying hydraulic pressure to the die ejection reservoir 312. This pressure acts upon the die ejection piston 310 (an annular shape in this example), moving the die ejection piston to the right in Fig. 3, thereby moving die ejection pins 320, the die holder 220 and the die 210 to the right in Fig. 3. By moving the die 210 to the right in Fig. 3, as described above, a formed work piece 5 can be ejected from the die (by a process described below) and removed from the press through work piece ejection hole 20. After formation of the work piece 5, the die 220 is moved to the right in Fig. 3, as described above, and the work piece 5 is separated from the work piece forming ends of the punches by moving specific punches in either the retraction direction A or the pressing direction B. The specific punches being moved and in which direction is determined for each particular work piece. The first cylinders (cylinders 110, 120, and 130) and the second cylinders (cylinders 140 and 150), in this example and the die housing 230 are held by frame 10. In the example, frame 10 has a first end plate 12 and a second end plate 14 held together by a at least one and preferably a plurality of rods (bolts) 16 and nuts 18. The rod or bolt preferably has a cross sectional area for a given bolt material that is able to withstand a pressure approximately equal to the sum of the respective surface areas of the force receiving ends of the pistons multiplied by the respective motive force being applied to each surface. These pressure values for a given bolt material and cross section can be readily ascertainable. For safety reasons it is of course preferable to exceed this calculated pressure by at least a factor of 2 and preferably 4. This can be done by adding additional bolts, choosing a stronger bolt material or a bolt with a wider diameter or any combination of these.

Hydraulic fluid may be channeled to the pressing surfaces of the outermost punches (the first punch 112 and the second

punch 152 in this example) by hydraulic fluid channels 350 in the first and second end plates 12, 14.

The hydraulic fluid for the various hydraulic fluid passages and channels is pressurized, for example, by a pressure source 360 as shown in Fig. 6. Hydraulic fluid lines 370 connect the pressure source 360 to the hydraulic fluid channels 350, the pressing hydraulic fluid passages (for example, 124), the retracting hydraulic fluid passages (for example, 125) and the die ejection reservoir 312.

In a preferred embodiment, the pressure source 360 has a plurality of valves, one valve for each hydraulic fluid line 370. By selectively operating the valves of the pressure source 360, the punches and the die ejection piston 310 can be selectively moved in either direction. In embodiments, the valves of the pressure source 360 are controlled by a microprocessor. For example, valves may be controlled by one time/pressure curve such that each punch begins pressing at substantially the same time, stops pressing at substantially the same time and presses the powder with substantially the same pressure even though different punches can have substantially different strokes. The controller preferably a microprocessor controls the rate at which each piston slides within the cylinder so that at a given point in time, the force per unit area^2 on each surface of the work piece is the same. Alternatively, the valves can be controlled so that each punch slides a predetermined distance in the cylinder, until a predetermined force is being applied to the respective first surface(s) and second surface(s)of the work piece or until a mechanical stop is reached within the piston cylinder.

In embodiments, the pressure source 360 supplies hydraulic fluid at one pressure and, therefore, each hydraulic fluid line 370 connected to an open valve supplies hydraulic fluid at the one pressure. It is preferable that the powder from which the work piece is formed is compressed at a uniform

pressure. The pressure at which any given material must be pressed to obtain a given density is generally known. Because the work piece forming end of each punch usually has a different surface area, each punch could require a different force to be applied to its force receiving surface to achieve the uniform pressure. In order to apply these potentially different forces to the pressing surfaces of different punches by hydraulic fluid at the one pressure, the area of the pressing surface of each punch is preferably individually determined. Due to this feature of such embodiments of the invention, it is not necessary to supply multiple pressure sources having different pressures.

As an alternative, the pressing surfaces of the punches could be made to have surface areas not specifically related to the areas of the corresponding punches, and the pressure of the hydraulic fluid applied to the pressing surface of each punch could be individually set to produce the desired pressing force of each punch.

Figure 7 shows an alternative embodiment of the present press wherein there is one first piston cylinder 210. First piston 212 reciprocally operates within piston cylinder 210. First punch 213 for forming a first surface of a work piece is operatively associated with first piston 212. Similarly, there is one second piston cylinder 240 wherein second piston 242 operates. Second punch 215 for forming a second surface on the work piece is operatively with second piston 242. First punch 213 has work piece formind end 223 opposite to the portion 228 at which it associates with the piston 212 and similarly second punch 215 has work piece forming end 225 opposite to the portion 231 at which it associates with piston 242. Pistons 212 and 242 respectively have retraction surface 221 and 223 and force receiving surfaces 229 and 233. First spacer cylinder 235 and second spacer cylinder 237 maintain piston cylinders 210 and 240 fixed relative to the die 310

which is in this embodiment fixed. Die holder cylinder 320 holds die 310 in a position to receive first work piece forming end 223 of first piston 212 and second work piece forming end of second piston 242. First cylinder 210, first spacer cylinder 235, die holder cylinder 32o, second cylinder 240 and second spacer cylinder 237 are held by frame 10 having first end plate 12 and second end plate 14. The first end plate 10 and second end plate 14 are held together by bolts (not shown).

In operation, starting from "fill" wherein from about ¼ to about 1 inch of first work piece forming end 223 of first punch 213 and from about ¼ to about 1 inch of second work piece forming end of second punch 215 each respectively sit inside die 310 thereby enclosing die 310 for containing powder material. Powder material to make a work piece is then introduced into die 310 through a conduit (not shown) and preferably fluidized. Hydraulic fluid moves through first inlet (not shown) to act on first force receiving end 229 of piston 212 sliding it within first piston cylinder 210 towards die 310. At the same time hydraulic fluid moves through second inlet (no shown) to act on second force receiving end 233 of piston 242 sliding it in the direction of die 310. Powder (not shown) in die 310 is thereby compressed between the work piece forming end 223 of first punch 213 and the work piece forming end 225 of second punch 215. Second retraction surface 233 is acted upon by hydraulic fluid entering into second cylinder 240 through retraction inlet 390 thereby moving second piston 242 away from die 310. The work piece formed is ejected by further application of hydraulic fluid on the force receiving end 229 of piston 212 causing piston 212 to travel toward and through die 310 a distance that is approximately equal to the height of the work piece thereby pushing the work piece out of the die 310. As will be immediately appreciated, the process by which the press of the

present invention presses and then ejects a work piece can involve any number of the above operational steps in the same or different order or combination and the invention should therefore not be construed as limited only to the above.

In preferred embodiments of the invention, the powder from which the work piece is produced is fluidized and/or pressurized to produce a substantially uniform density throughout the powder in the die during pressing. Examples of such powder fluidization and pressurization are shown in U.S. Patent No. 5,885,625, issued on March 23, 1999; U.S. Patent No. 5,945,135 issued on August 31, 1999 and U.S. Patent No. 5, 897,826 issued on April 27, 1999, which are hereby incorporated in their entirety herein by reference. Using such filling techniques, a press of the present invention can be operated with its major axis in the horizontal position, unlike conventional presses which rely mainly on gravity for their fill. Additionally, because the density of the powder is uniform in the die the press need not withstand the large shear stresses encountered with conventional presses, the number of parts of the press may be greatly reduced (for example, approximately 30 parts, other than seals, versus approximately 2000 parts in a conventional press). Also, the powder is isolated from the operating environment enabling the safe usage of a number of materials. Due to the compact size and reduced number of parts, a press of the invention can be produced for a fraction of the cost of a conventional press. Moreover, since the power supply for a press of the present invention is independent and external to the press, it is highly portable and can be attached and disattached to the power supply as needed. In some embodiments of the present press many of the parts of may not be reusable to produce a different work piece. Nonetheless, the substantially reduced cost of the press as compared to a conventional press results in reduced manufacturing costs of a given work piece such that

it can economically be dedicated to the manufacture of a single part.

While the invention has been described by using the example of a hydraulic press with concentrically positioned punches, it should be noted that other known force producing sources and other relative punch positions can be used. For example, mechanical pressing, pneumatic pressing, piezoelectric or electromagnetism can be used to apply force to the punches. In addition, punches having work piece forming ends other than cylinders and having axes that are not concentric can be used.

The present invention is further directed to a method for forming a work piece. The method comprises introducing a powder material into a die, preferably creating a uniform density of powder in the die by fluidizing the powder in the die and pressing the material in the die from a first direction with a first set of at least one work piece forming punches. Operatively associating the work piece forming punches with a first set of at least one pistons and pressing the material in the die by directly applying a motive force to a force receiving end of each of the first set of at least one pistons thereby sliding each piston within a first piston cylinder in a direction towards the die. Each of the first piston cylinders is fixed relative to each other.

The method can optionally further comprise the step of pressing the material in the die from a second direction opposite the first direction with a second set of at least one work piece forming punches respectively operatively associated with a second set of at least one pistons. Like the first set of work piece forming punches, the material is pressed in the die by directly applying a motive force to the motive force receiving end of each of the second set of at least one piston(s) thereby sliding each within a second piston cylinder

in a first direction towards the die. Each of the second piston cylinders is also fixed relative to each other. In this method the first and/or second direction can be along a horizontal plane.

In this method the step of directly applying the motive force to the force receiving end of each of the first pistons is carried out by delivering hydraulic fluid into each of the first piston cylinders.

In a further embodiment, the present invention is directed to a modular manufacturing assembly. The assembly comprises an independent power source and at least one manufacturing module remotely associated therewith..Each manufacturing module is comprised of at least one tool to form a work piece. Preferably, the tool is operatively associated with a first end of a piston having a second force receiving end. There is at least one force applying assembly configured to apply force directly to the force receiving end of the piston. The manufacturing module is operatively and reciprocally connected to and receives power from the independent power source. In a particularly preferred embodiment, the tool is a stamping press configured to stamp out parts or the tool is configured as a forging press. Any number of different manufacturing technologies can be used in conjunction with the modular manufacturing assembly and the invention should therefore not be construed as being limited only to forging and stamping.

While the present invention has been described with reference to embodiments thereof, it is to be understood that the invention is not limited to the described embodiments or constructions. To the contrary, the invention is intended to cover various modifications and equivalent arrangements. In addition, while the various elements of the disclosed invention are shown in various combinations and configurations, which are exemplary, other combinations and

configurations, including more, less or only a single element, are also within the spirit and scope of the invention.

WHAT IS CLAIMED IS:

1. A powder press for forming a work piece, comprising:

at least one punch having an end for pressing a powder material to form a work piece; said punch being operatively associated with a first end of a piston, said piston having a second force receiving end;

at least one force applying assembly configured to apply pressing force directly to the force receiving end;

a die to receive and contain the powder and having a hole positioned to receive the end of the punch;

means associated with the die for creating a substantially uniform distribution of powder in the die; and

a source of power for engaging said at least one force applying assembly, said source of power being external to and independent from said powder press.

2. A powder press assembly comprising

an independent power source; and

at least one pressing module remotely associated therewith, each said at least one pressing module comprised of at least one punch having an end for pressing a powder material to form a work piece, said at least one punch being operatively associated with a first end of a piston having a second force receiving end; at least one force applying assembly configured to apply pressing force directly to the force receiving end; said at least one pressing module being operatively and removably connected to and receiving power from said independent power source; and a die to receive and contain the powder, said die having a hole positioned to receive the end of the punch.

3. The powder press assembly according to claim 2 further comprising means attached to the die for delivering powder into the die and creating a substantially uniform distribution of powder in the die.

4. The powder press assembly according to claim 2, comprising a plurality of pressing modules remotely associated with said independent power source.

5. The powder press assembly according to claim 2, further comprising at least one pressing station remotely connected to said powder source, wherein each of said at least one pressing module is removably attached respectively at one of said at least one pressing station.

6. A powder press for forming a work piece, comprising:

at least one punch having an end for pressing a powder material to form a work piece, said at least one punch being operatively associated with a force receiving piston;

at least one force applying assembly configured to apply pressing force directly to the force receiving piston; and

a die to receive and contain the powder and having a hole positioned to receive the end of the punch;

means associated with the die for creating a substantially uniform distribution of powder in the die.

7. The powder press according to claim 6 wherein said means for creating a substantially uniform distribution comprises a powder fluidizing apparatus.

8. The powder press according to claim 6 further being operatively associated with an independent power source, said independent powder source being free standing and remotely located from said press.

9. A powder press for forming a work piece, comprising

at least one punch;

at least one piston having a first end and a second force receiving end;

said punch being operatively associated with the first end and extending in a first direction;

at least one force applying assembly configured to apply pressing force directly to the force receiving end of the piston; and

a die to receive and contain the powder and having a hole positioned to receive the end of the punch; and

means associated with the die for delivering powder into the die and for creating a substantially uniform distribution of powder in the die.

10. The powder press of claim 9, wherein said means for delivering the powder to the die comprises a means for fluidization of the powder in the die.

11. The powder press of claim 9, wherein said punch being operatively associated with said first end of said at least one piston is removable therefrom.

12. The powder press of claim 9, wherein said punch being operatively associated with said first end of said at least one piston comprises a single monolithic part.

13. The powder press of claim 9 further comprising at least one second punch extending a second direction opposite that of said at least one first punch and towards said die.

14. The powder press of claim 13 wherein said at least one second punch is fixed.

15. The powder press of claim 13 wherein said at least one second punch is operatively associated with a first end of at least one second piston having a second force receiving end.

16. A powder press for forming a work piece having a height H_{wp} from powder having a powder fill ratio R_{pf}, said press comprising:

at least one first piston cylinder having a first piston reciprocally slidable within it, the first piston having a force receiving end within the cylinder and a work piece forming end for forming a first surface of a work piece, said work piece forming end having a surface area A_{wp} and extending beyond the cylinder in a first direction; said force receiving end directly engaging a motive force F_{m1} for sliding said piston within said at least one first piston cylinder to

generate a force to be applied to said first surface of the work piece F_{wp1} and said force receiving end having a surface area A_{fr1} approximately equal to or greater than:

$$\frac{A_{wp1} \times F_{wp1}}{F_{m1}}$$; and

a die for defining an outer surface of the work piece, said die having an opening positioned to receive the work piece forming end of the piston and an opening to receive the powder.

17. The powder press of claim 16, wherein said work piece forming end is comprised of a first work piece forming punch being operatively associated with a second end of the first piston.

18. The powder press of claim 16, wherein the first piston and the first work piece forming punch are comprised of a single monolithic part.

19. The powder press of claim 16, wherein to form the work piece the distance the first piston is slidable toward said die is approximately equal to $(H_{wp} \times R_{pf}) - H_{wp}$.

20. The powder press of claim 17, wherein to eject the work piece the first piston is further slidable within said at least one piston cylinder toward said die for a distance that is approximately equal to the height of the work piece.

21. The powder press of claim 16, wherein to eject the work piece the distance the first piston is slidable within said at least one piston cylinder toward said die is approximately equal to the height of the work piece x fill ratio of the powder.

22. The powder press of claim 16, wherein said first piston is slidable within said at least one first piston cylinder toward and into said die until it slides a predetermined distance in the cylinder.

23. The powder press of claim 16, wherein said first piston is slidable within said at least one first piston

cylinder toward said die until a predetermined force is being applied to said first surface of the work piece.

24. The powder press of claim 16, wherein said first piston is slidable within said at least one first piston cylinder toward and into said die until a mechanical stop is reached within said at least one first piston cylinder.

25. The powder press of claim 16, further comprising a fixed punch for forming a second surface of said work piece, said fixed punch extending in a second direction opposite said first direction and towards said die.

26. The powder press of claim 16, further comprising a controller for controlling a rate at which each said first piston is slidable within each said first piston cylinder so that at a point in time force/unit area^2 being applied to each said first surface of the work piece is the same.

27. The powder press of claim 16, further comprising a controller for controlling a rate at which each first piston is slidable within said at least one first piston cylinder so that each first piston reaches each first surface of the work piece at the same point in time.

28. The powder press of claim 16 wherein each of said at least one first piston cylinder are fixed relative to each other so that each said at least one first piston cylinder is axially and vertically aligned relative to another of said at least one first piston cylinder.

29. The powder press of claim 28, wherein each of said at least one first piston cylinder are fixed relative to each other by at least one bolt, a cross sectional area of said at least one bolt being so dimensioned for a given bolt material to withstand a pressure approximately equal to or greater than $\Sigma[A_{fr1} \times F_{m1}]$.

30. The powder press of claim 16, further comprising at least one second piston cylinder having a second piston reciprocally slidable within it, the second piston having a

force receiving end within the cylinder and a work piece forming end for forming a second surface of a work piece, said work piece forming end having a surface area A_{w2} and extending beyond the cylinder; said force receiving end directly engaging a motive force F_{m2} for sliding said piston within said at least one second piston cylinder to generate a force F_{wp2} to be applied to said first surface of the work piece and said force receiving end having a surface area A_{fr2} approximately equal to or greater than:

$$\frac{A_{wp2} \times F_{wp2}}{F_{m2}}$$

31. The powder press of claim 30, wherein to form the work piece said first piston and said second piston are each respectively slidable toward said die for a distance that is approximately equal to:

$$\frac{(H_{wp} \times R_{f}) - H_{wp}}{2}$$

32. The powder press of claim 31, wherein to eject the work piece the second piston is further slidable within said at least one second piston cylinder toward said die for a distance that is approximately equal to H_{wp}.

33. The powder press of claim 30, wherein to eject the work piece the second piston is slidable toward said die for a distance that is approximately equal to $H_{wp} \times R_{pf}$ the die.

34. The powder press of claim 30, wherein said second piston is slidable within said at least one second piston cylinder toward said die until it slides a predetermined distance in the cylinder.

35. The powder press of claim 30, further comprising a controller for controlling a rate at which each said first piston is slidable within each said first piston cylinder so that at a given point in time force/unit area^2 on each said first surface of the work piece is the same and for controlling a rate at which each said second piston is slidable within each said second piston cylinder so that at

any given point in time force/unit area² on each said second surface of the work piece is the same..

36. The powder press of claim 35, wherein said controller controls the rate at which each first piston is slidable within said at least one first piston cylinder and the rate at which each second piston is slidable within said at least one second piston cylinder so that each work piece forming end of the first piston reaches each first surface of the work piece at the same point in time that each work piece forming end of the second piston reaches each second surface of the work piece.

37. The powder press of claim 30, wherein said second piston is slidable within said at least one second piston cylinder toward said die until a mechanical stop is reached within said at least one second piston cylinder.

38. The powder press of claim 30, wherein the work piece forming end of the second piston extends in a direction opposite to said first direction and along the same axis with the first piston.

39. The powder press of claim 30, wherein said at least one first piston cylinder and said at least one second piston cylinder are fixed relative to each other, and each of said at least one first piston cylinder is axially and vertically aligned relative to each of said at least one second piston cylinder.

40. The powder press of claim 39, wherein said at least one first piston cylinder and said at least one second piston cylinder are fixed relative to each other by at least one bolt, a cross sectional area of said at least one bolt being so dimensioned for a given bolt material to withstand a pressure approximately equal to or greater than

$$\Sigma[A_{fr1} \times F_{m1}] + \Sigma[A_{fr2} \times F_{m2}]$$

41. The powder press of claim 39, comprising a plurality of said first piston cylinders situated successively closer to

the die cavity, whereby each said at least one first piston cylinder is axially and vertically aligned relative to another said at least one first piston cylinder.

42. The powder press of claim 41, comprising a plurality of said second piston cylinders situated successively closer to the die cavity, whereby each said at least one second piston cylinder is axially and vertically aligned relative to another said at least one second piston cylinder

43. The powder press according to claim 41, wherein the first piston within each succeeding first piston cylinder extends through and is axially movable along an inner peripheral surface defining a cylindrical void through a directly preceding first piston.

44. The powder press according to claim 43, wherein said second piston within each succeeding second piston cylinder extends through and is axially movable along an inner peripheral surface defining a cylindrical void through a directly preceding second piston.

45. The powder press of claim 16, further comprising means attached to the die for delivering powder to the die and fluidizing the powder in the die.

46. The powder press of claim 30, wherein each said at least one first piston cylinder and each said at least one second piston cylinder is a hydraulic cylinder and the motive force for sliding said first piston and said second piston is provided by hydraulic fluid.

47. The powder press of claim 30, wherein each said at least one first piston cylinder and each said at least one second piston cylinder is a pneumatic cylinder and the motive force for sliding said first piston and said second piston is provided by air.

48. The powder press of claim 30, wherein the motive force for sliding said first piston and said second piston is mechanical.

49. The powder press of claim 30, wherein said first piston cylinders are adjacent to and engage each other.

50. The powder press of claim 30, wherein said second piston cylinders are adjacent to and engage each other.

51. The powder press of claim 30, wherein said first piston cylinders are adjacent to and engage each other and said second piston cylinders are adjacent to and engage each other.

52. The powder press of claim 30, wherein said work piece forming end of said first piston and said work piece forming end of said second piston work piece lengthwise along a horizontal plane.

53. A powder press for forming a work piece, comprising:

a frame;

a first monolithic punch having a first axis, a first work piece forming end for forming a first surface of the work piece and a first force receiving end;

a first force applying assembly directly engaging the first force receiving end for applying force along the first axis of the first monolithic punch, the first force applying assembly being fixed relative to the frame along the first axis.

54. The powder press of claim 38, further comprising

a second monolithic punch having a second axis, a second work piece forming end for forming the work piece and a second force receiving end; and

a second force applying assembly directly engaging the second force receiving end for applying force along the second axis of the second monolithic punch, the second force applying assembly being fixed relative to the frame along the second axis.

55. The powder press of claim 39, wherein the first work piece forming end and the second work piece forming end are concentrically arranged to form a same side of the work piece.

56. The powder press of claim 39, wherein the first work piece forming end and the second work piece forming end are arranged at opposition to form opposite sides of the work piece.

57. The powder press of claim 39, wherein the first axis and the second axis are horizontal.

58. The powder press of claim 39, wherein the first force applying assembly and the second force applying assembly are hydraulic force applying assemblies.

59. The powder press of claim 39, wherein the first force applying assembly and the second force applying assembly are mechanical force applying assemblies.

60. A method for forming a work piece, comprising the steps of:

introducing a powder material into a die;

creating a substantially uniform distribution of powder material in the die;

pressing the powder material in the die from a first direction with a first set of at least one work piece forming punches respectively operatively associated with a first set of at least one pistons by directly applying a motive force to each of the first set of at least one pistons thereby sliding each within a first piston cylinder in a second direction towards the die, each of said first piston cylinder being fixed relative to each other.

61. The method of claim 60, further comprising pressing the material in the die from the second direction opposite the first direction with a second set of at least one work piece forming punches respectively operatively associated with a second set of at least one pistons by directly applying a motive force to each of the second set of at least one pistons thereby sliding each within a second piston cylinder in the first direction towards the die, each of said second piston cylinders being fixed relative to each other.

62. The method of claim 60, wherein the first direction is along a horizontal plane.

63. The method of claim 62, wherein the second direction is along a horizontal plane.

64. The method of claim 60, further comprising the step of fluidizing the powder after delivering it.

65. The method of claim 60, wherein the motive force is directly applied to each of said first pistons by delivering hydraulic fluid into each of the first piston cylinders.

66. The method of claim 60, wherein the step of pressing the material is carried out by directly applying a uniform pressure to each of said first set of at least one work piece forming punches.

67. A method of forming a work piece, comprising the steps of:

introducing a powder material into a die;

applying a first force directly to a first force receiving end of a first piston within a first piston cylinder to move said first piston within said first piston cylinder towards the die thereby pressing the material in the die with a first work piece forming end of the first piston extending out of the first piston cylinder in a first direction.

68. The method of claim 67, further comprising applying a second force directly to a second force receiving end of a second piston within a second piston cylinder and thereby pressing the material in the die with a second work piece forming end of the second piston extending out of the second piston cylinder in a second direction.

69. The method of claim 68, wherein the first direction is the same as the second direction.

70. The method of claim 68, wherein the first direction is opposite the second direction.

71. The method of claim 68, wherein the first piston cylinder and the second piston cylinder are hydraulic

cylinders and the first piston and the second piston are hydraulically operated.

72. The method of claim 67, further comprising the step of selecting a surface area of the first force receiving end so that the first work piece forming end presses on the work piece with a predetermined pressure and selecting a surface area of the second force receiving end so that the second work piece forming end presses on the work piece with the same predetermined pressure.

73. The method of claim 67, further comprising the step of setting a distance for the first piston to move within the first piston cylinder based on the work piece being formed.

74. The method of claim 73, further comprising the step of setting a distance for the second piston to move within the second piston cylinder based on the work piece being formed.

75. An apparatus for forming a work piece, comprising:

means for introducing a powder material into a die;

means for creating a substantially uniform distribution of the powder material within the die;

means for pressing the material in the die from a first direction by directly engaging at least one first piston respectively operatively associated with at least one work piece forming punch, each said at least one first piston being slidable within a piston cylinder, the piston cylinders being fixed relative to each other.

76. The powder press according to claim 75, further comprising means for pressing the material in the die from a second direction by directly engaging at least one second piston respectively operatively associated with at least one work piece forming punch, each said at least one second piston being slidable within a piston cylinder, the piston cylinders being fixed relative to each other.

77. An apparatus for forming a work piece, comprising:

means for introducing a powder material into a die;

means for creating a substantially uniform distribution of powder material in the die;

means for applying force directly to a force receiving end of a piston within a piston cylinder and thereby pressing the material in the die with a work piece forming end of the piston extending out of the piston cylinder.

78. The powder press according to claim 75, further comprising:

means for generating power to apply force to the force receiving end of the piston cylinder, said means for generating force being remote from and reciprocally attached to said force applying assembly.

79. A powder press for forming a work piece, comprising:

at least one punch having an end for pressing a powder material to form a work piece;

at least one force applying assembly configured to apply pressing force directly to the punch; and

a die to receive and contain the powder and having a hole positioned to receive the end of the punch;

said powder press being free of movable platens.

80. A powder press for forming a work piece having a height H_{wp} of powder having a powder fill ratio R_{pf}, said press comprising:

at least one first piston cylinder having a first piston reciprocally slidable within it, the first piston having a force receiving end within the cylinder and a work piece forming end for forming a first surface of a work piece, said work piece forming end having a surface area A_{wp} and extending beyond the cylinder in a first direction; said force receiving end directly engaging a motive force F_{m1} for sliding said piston within said at least one first piston cylinder to generate a force to be applied to said first surface of the work piece F_{wp1} and said force receiving end having a surface area A_{fr1} approximately equal to or greater than:

$$\frac{A_{wp1} \times F_{wp1}}{F_{m1}}$$; and

a die for defining an outer surface of the work piece, said die having an opening positioned to receive the work piece forming end of the piston and an opening to receive the powder; and

means attached to the die for delivering powder into the die and creating a substantially uniform distribution of powder in the die.

81. The powder press of claim 80, wherein said means for delivering the powder to the die comprises a means for fluidization of the powder in the die.

82. The powder press of claim 80, wherein said work piece forming end is comprised of a first work piece forming punch being operatively associated with a second end of the first piston.

83. The powder press of claim 80, wherein the first piston and the first work piece forming punch are comprised of a single monolithic part.

84. The powder press of claim 80, wherein to form the work piece the distance the first piston is slidable toward said die is approximately equal to $(H_{wp} \times R_{pf}) - H_{wp}$ and to eject the work piece the first piston is further slidable within said at least one piston cylinder toward said die for a distance that is approximately equal to the height of the work piece.

85. The powder press of claim 80, wherein to eject the work piece the total distance the first piston is slidable within said at least one piston cylinder toward said die is approximately equal to the height of the work piece x fill ratio of the powder.

86. The powder press of claim 80, wherein said first piston is slidable within said at least one first piston cylinder toward and into said die until it slides a predetermined distance in the cylinder.

87. The powder press of claim 80, wherein said first piston is slidable within said at least one first piston cylinder toward said die until a predetermined force is being applied to said first surface of the work piece.

88. The powder press of claim 80, wherein said first piston is slidable within said at least one first piston cylinder toward and into said die until a mechanical stop is reached within said at least one first piston cylinder.

89. The powder press of claim 80, further comprising a fixed punch for forming a second surface of said work piece, said fixed punch extending in a second direction opposite said first direction and towards said die.

90. The powder press of claim 80, further comprising a controller for controlling a rate at which each said first piston is slidable within each said first piston cylinder so that at a point in time force/unit area^2 being applied to each said first surface of the work piece is the same.

91. The powder press of claim 80, further comprising a controller for controlling a rate at which each first piston is slidable within said at least one first piston cylinder so that each first piston reaches each first surface of the work piece at the same point in time.

92. The powder press of claim 80, wherein each of said at least one first piston cylinder are fixed relative to each other so that each said at least one first piston cylinder is axially and vertically aligned relative to another of said at least one first piston cylinder.

93. The powder press of claim 92, wherein each of said at least one first piston cylinder are fixed relative to each other by at least one bolt, a cross sectional area of said at least one bolt being so dimensioned for a given bolt material to withstand a pressure approximately equal to or greater than $\Sigma[A_{tr1} \times F_{a1}]$.

94. The powder press of claim 80, further comprising at least one second piston cylinder having a second piston reciprocally slidable within it, the second piston having a force receiving end within the cylinder and a work piece forming end for forming a second surface of a work piece, said work piece forming end having a surface area A_{w2} and extending beyond the cylinder; said force receiving end directly engaging a motive force F_{m2} for sliding said piston within said at least one second piston cylinder to generate a force F_{wp2} to be applied to said first surface of the work piece and said force receiving end having a surface area A_{fr2} approximately equal to or greater than:

$$\frac{A_{wp2} \times F_{wp2}}{F_{m2}}$$

95. The powder press of claim 94, wherein to form the work piece said first piston and said second piston are each respectively slidable toward said die for a distance that is approximately equal to:

$$\frac{(H_{wp} \times R_f) - H_{wp}}{2}$$

96. The powder press of claim 95, wherein to eject the work piece the second piston is further slidable within said at least one second piston cylinder toward said die for a total distance that is approximately equal to H_{wp}.

97. The powder press of claim 96, wherein to eject the work piece the second piston is slidable toward said die for a distance that is approximately equal to $H_{wp} \times R_{pf}$ the die.

98. The powder press of claim 96, wherein said second piston is slidable within said at least one second piston cylinder toward said die until it slides a predetermined distance in the cylinder.

99. The powder press of claim 96, further comprising a controller for controlling a rate at which each said first piston is slidable within each said first piston cylinder so that at a given point in time force/unit area^2 on each said

first surface of the work piece is the same and for controlling a rate at which each said second piston is slidable within each said second piston cylinder so that at any given point in time force/unit area^2 on each said second surface of the work piece is the same.

100. The powder press of claim 99, wherein said controller controls the rate at which each first piston is slidable within said at least one first piston cylinder and the rate at which each second piston is slidable within said at least one second piston cylinder so that each work piece forming end of the first piston reaches each first surface of the work piece at the same point in time that each work piece forming end of the second piston reaches each second surface of the work piece.

101. The powder press of claim 96, further comprising a mechanical stop within said at least one second piston cylinder for mechanically stopping said second piston as it slides within said at least one second piston cylinder toward said die.

102. The powder press of claim 96, wherein the work piece forming end of the second piston extends in a direction opposite to said first direction and along the same axis with the first piston.

103. The powder press of claim 96, wherein said at least one first piston cylinder and said at least one second piston cylinder are fixed relative to each other, and each of said at least one first piston cylinder is axially and vertically aligned relative to each of said at least one second piston cylinder.

104. The powder press of claim 103, wherein said at least one first piston cylinder and said at least one second piston cylinder are fixed relative to each other by at least one bolt, a cross sectional area of said at least one bolt being

so dimensioned for a given bolt material to withstand a pressure approximately equal to or greater than

$$\Sigma[A_{tr1} \times F_{m1}] + \Sigma[A_{tr2} \times F_{m2}]$$

105. The powder press of claim 8, comprising a plurality of said first piston cylinders situated successively closer to the die cavity, whereby each said at least one first piston cylinder is axially and vertically aligned relative to another said at least one first piston cylinder and a plurality of said second piston cylinders situated successively closer to the die cavity, whereby each said at least one second piston cylinder is axially and vertically aligned relative to another said at least one second piston cylinder

106. The powder press according to claim 105, wherein the first piston within each succeeding first piston cylinder extends through and is axially movable along an inner peripheral surface defining a cylindrical void through a directly preceding first piston and wherein said second piston within each succeeding second piston cylinder extends through and is axially movable along an inner peripheral surface defining a cylindrical void through a directly preceding second piston.

107. The powder press of claim 94, wherein each said at least one first piston cylinder and each said at least one second piston cylinder is a hydraulic cylinder and the motive force for sliding said first piston and said second piston is provided by hydraulic fluid.

108. The powder press of claim 94, wherein each said at least one first piston cylinder and each said at least one second piston cylinder is a pneumatic cylinder and the motive force for sliding said first piston and said second piston is provided by air.

109. The powder press of claim 94, wherein the motive force for sliding said first piston and said second piston is mechanical.

110. The powder press of claim 94, wherein said first piston cylinders are adjacent to and engage each other and said second piston cylinders are adjacent to and engage each other.

111. A modular manufacturing assembly comprising
an independent power source; and
at least one manufacturing module remotely associated therewith, each said at least one manufacturing module comprised of at least one tool to form a work piece, said at least one tool being operatively associated with a first end of a piston having a second force receiving end; at least one force applying assembly configured to apply force directly to the force receiving end; said at least one manufacturing module being operatively and reciprocally connected to and receiving power from said independent power source.

112. The modular manufacturing assembly according to claim 111, wherein said tool is configured as a stamp.

113. The modular manufacturing assembly according to claim 111, wherein said tool is configured as a forging press.

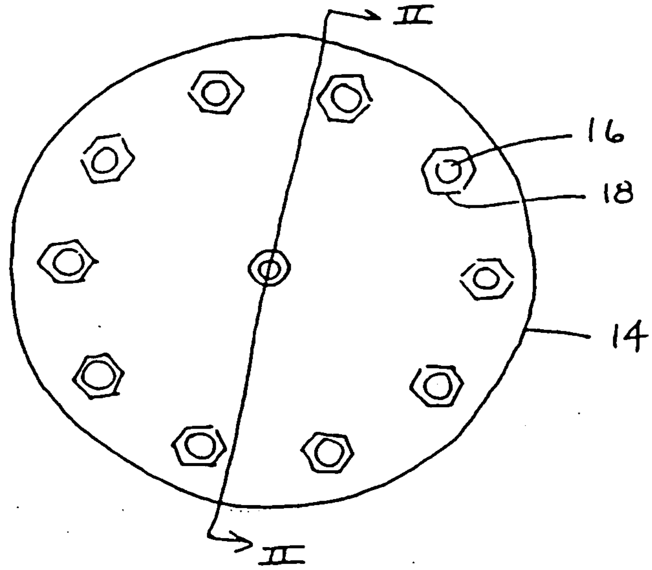

FIGURE 1

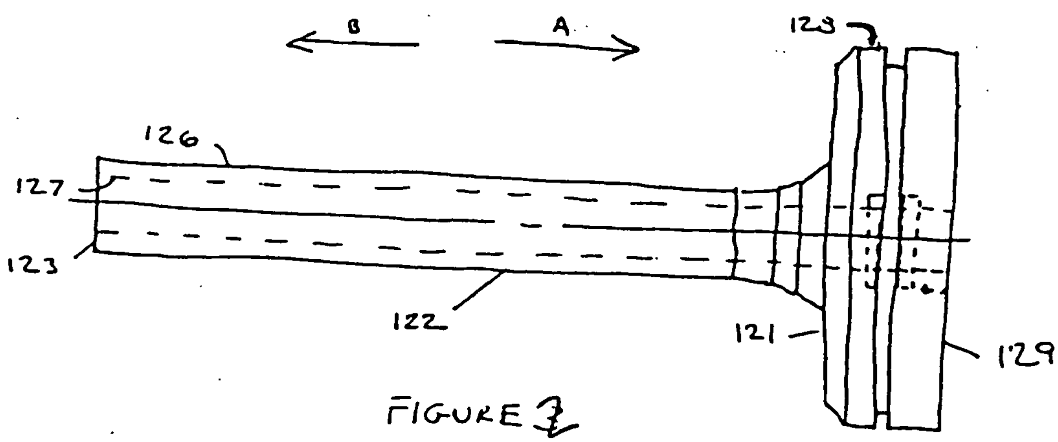

FIGURE 2

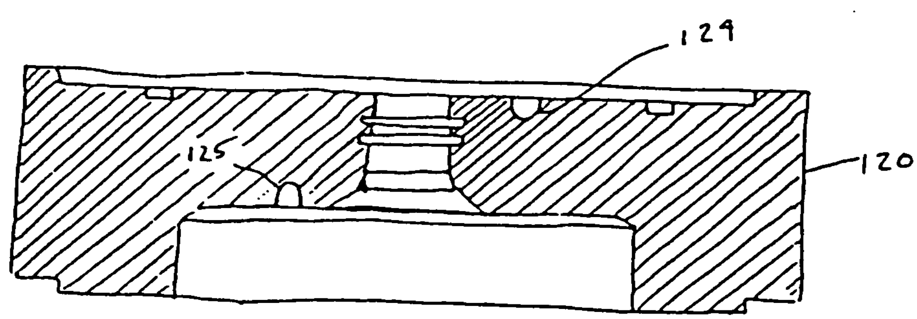

FIGURE 3

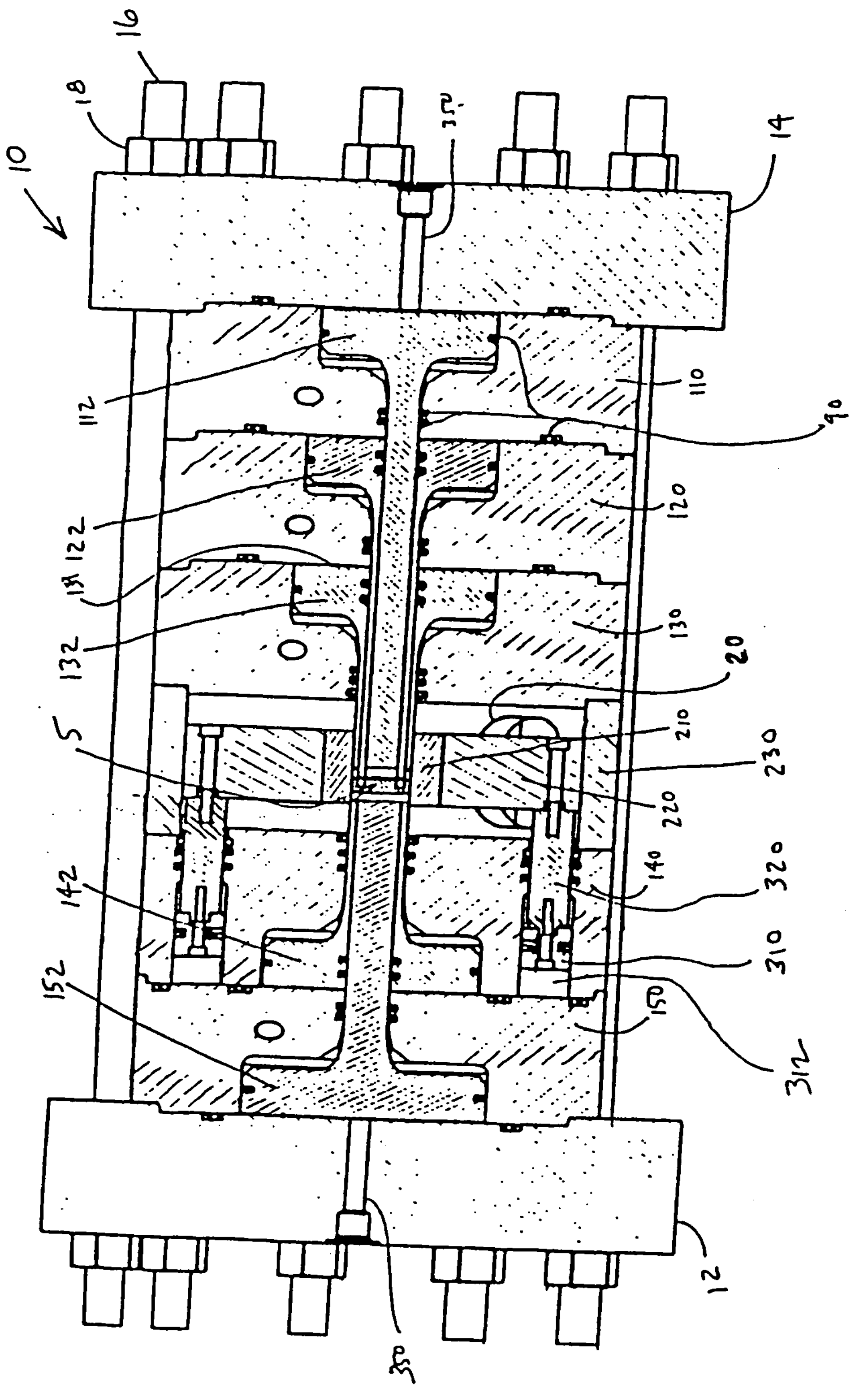
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FIGURE 4

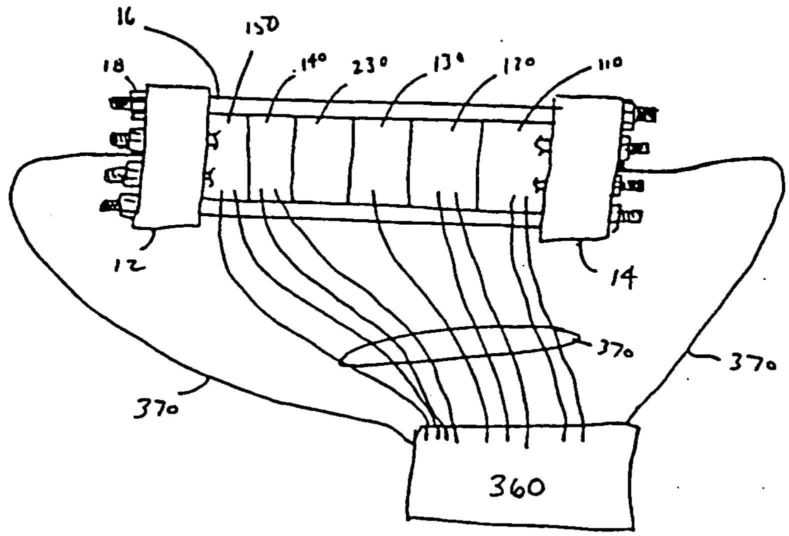

FIGURE 5

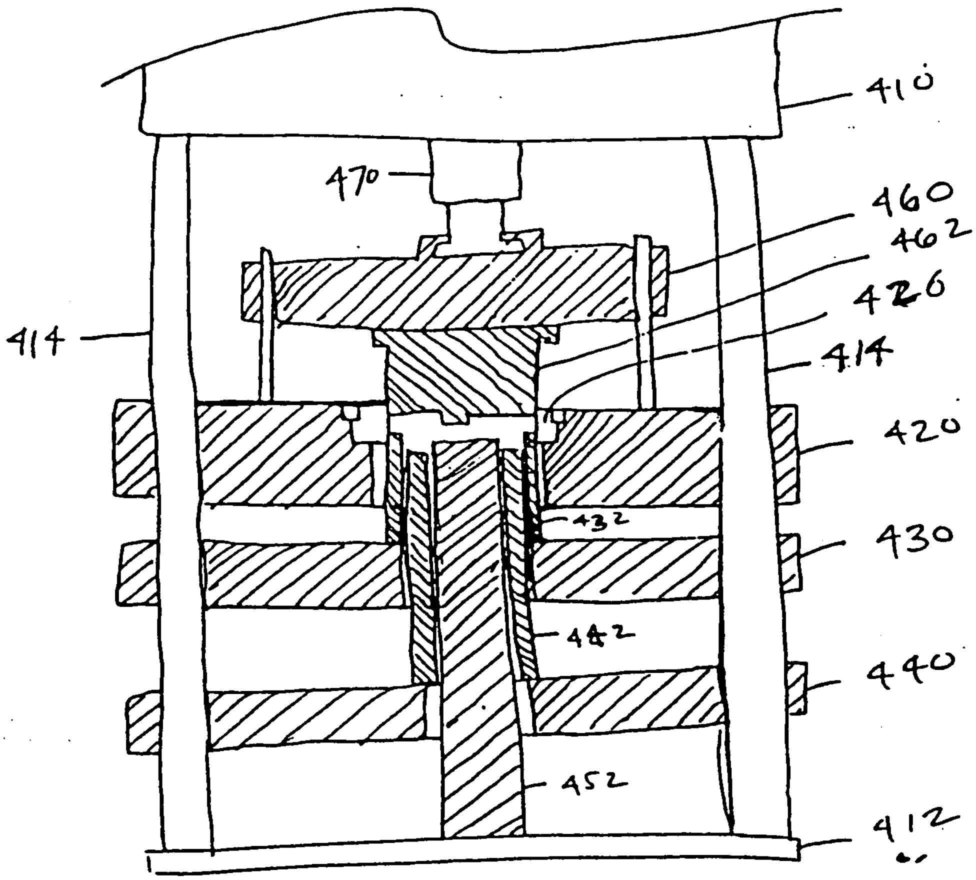

FIGURE 6

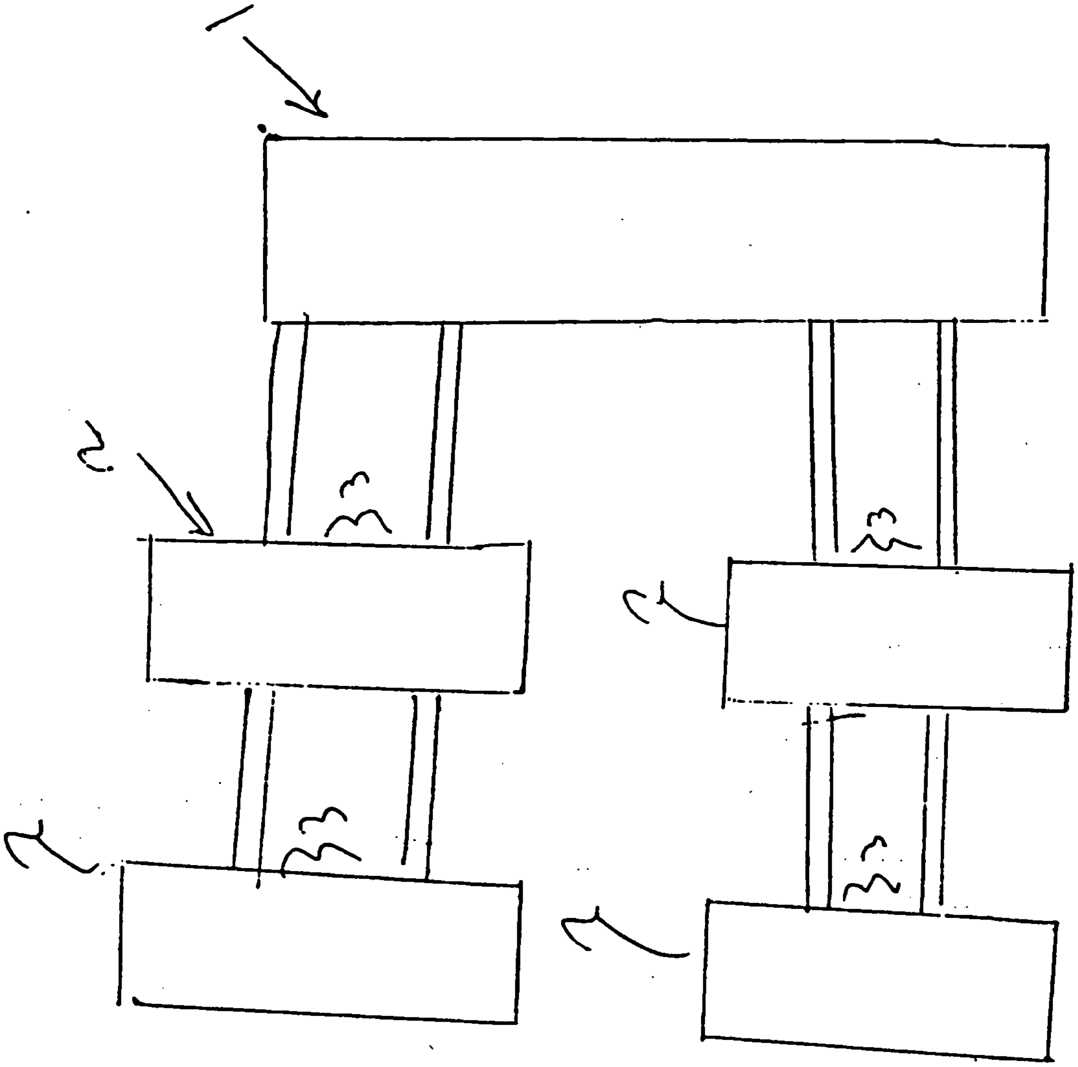

Fig 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/20613

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :B29C 43/34
US CL : 264/109.328.2. 517: 425/78. 260.449.258
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 264/109.328.2. 517.442: 425/60.78.260.253. 254.258.355.447.448.449.219

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
East and West

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,897,826 A (LASHMORE et al) 27 April 1999, see entire document.	1-15, and 67-80
Y	US 5,885,625 A (BEANE et al) 23 MARCH 1999, see entire document.	1-15 and 67-80
Y	US 5,074,774 A (NOSE et al) 24 December 1991, see entire document.	1-15 and 67-80
A	US 4,260,346 A (ANDERSON, Jr. et al) 7 April 1981, see entire document.	1-80
A	US 3,647,333 A (SMITH) 7 March 1972, see entire document.	1-80
A	US 4,518,335 A (PUJARI) 21 May 1985, see entire document.	1-80

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
03 OCTOBER 2000	18 OCT 2000

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